SuperNEMO

Questionnaire

for Joint session of the PAC for Particle Physics and the PAC for Nuclear Physics for the assessment of the JINR Neutrino Projects

Investigations of the 2β-decay processes Se-82 with SuperNEMO detector

PART A: Achievements

1. Contributions of the JINR group:

-List the contributions of the JINR group in hardware (including use of JINR computing resources for the project), software development and physics analyses

1. Production in association with the Prague TU of 720 blocks of plastic scintillators for the complete program of the Demonstrator calorimeter.
2. Production of plastic scintillators (PS) for the VETO system. VETO scintillator sizes 308 x 310 x 150 mm, PMTs 5” R6594 HAMAMATSU, 400 euro/block x 60 =24 keuro.
3. 100 photomultipliers, 8" R5912-03, ultra low-background, high quantum efficiency (QE=30%) produced by HAMAMATSU are purchased - 100 keuro.
4. 7 crates for calorimeter electronics were purchased - 39.5 keuro.
5. 1.5 kg of enriched ^{82}Se was purchased by JINR as sources of the double beta decay.
6. 3.5 kg of enriched ^{82}Se was purified in JINR using our original unique method.
7. Signal and high-voltage cables have been produced for the track detector of the Demonstrator.
8. Two ultra-low-background HPGe-detectors (600 cm3) were purchased to check the radioactive contamination of materials for the Demonstrator. Measurements of the double beta decay to excited isotope states were carried out also using this detector.
9. Running expenses of SuperNEMO experiment at LSM. JINR contribution to the infrastructure of the LSM – 20 keuro/yr.

-List the responsibilities of JINR group members within the management structure of the collaboration, if any, giving the name of the JINR member, the managerial role and the appointment period.

1. Our group was responsible for R&D of new scintillators and especially for the VETO system (Leader - I.B. Nemchenok).

2. The radiochemistry JINR Group (Leader D.Filosofov) was responsible for purification of ^{82}Se used to produce source foil. This is most critical part of work for the project. A clean room has been created at JINR specially to solve this task, a purification method was developed and a facility for radiochemical purification of ^{82}Se was developed.

3. V.Timkin has taken essential part in development and construction of the calorimeter.

4. V.Tretyak is the leader of data analysis and publication efforts for all NEMO-3 data. New results on the double beta decay of isotopes: ^{48}Ca, ^{82}Se, ^{96}Zr,^{100}Mo, ^{116}Cd, ^{130}Te, and ^{150}Nd (NEMO-3) have been obtained and articles on these results have been prepared and published under V.Tretyak leadership.

5. Software team (Leader Yu.Shitov) is responsible for simulation of the SuperNEMO/Demonstrator, development of data processing programs.

6. Electronics team (Leader A.Salamatin) was responsible for cabling.

7. O.Kochetov is the main coordinator of all the JINR team and member of scientific council of collaboration SuperNEMO.

2. Publications:

-List the papers published in the refereed literature (no conference proceedings) in which the JINR group had a major contribution (e.g. author of the analysis, promoter of the experiment, corresponding author, realization of a key equipment etc.). Give title of paper, reference and describe in 1-2 sentences the JINR contribution. Only papers published since the last approval of the project should be listed.

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[1] R. Arnold et al., “Detailed studies of Mo-100 two-neutrino double beta decay in NEMO-3”, Eur. Phys. J. C (2019) 79:440. DOI: 10.1140/epjc/s10052-019-6948-4

Author of analysis, text of the paper and corresponding author V.Tretyak is from JINR group.

[2] Alimardon V.Rakhimov et al., “Development of methods for the preparation of radiopure Se-82 sources for the SuperNEMO neutrinoless double-beta decay experiment”, Radiochimica Acta, 2020; 108(2): 87-97. DOI: 10.1515/ract-2019-3129.

The purification method is developed and applied by JINR group. Author of the text of the paper and corresponding author is from JINR group.

[3] R. Hodak et al., “Charactirization and Long-term Performance of the Radon Trapping Facility Operating at the Modane Underground Laboratory”, Journal of Physics G: Nuclear and Particle Physics 46 (2019)115105 (17pp). DOI: 10.1088/1361-6471/ab368e. Participation in the development, construction and tests.

[4] R. Arnold et al., NEMO-3 Collaboration, “Search for the double beta decay Se-82 to the excited states of Kr-82 with NEMO-3”, Nuclear Physics A v 996 (2020) 121701. DOI: 10.1016/j.nucl.physa.2020.121701.

Author of analysis, text of the paper V.Tretyak is from JINR group.

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3. PhD theses:

-List the PhD theses completed within the last 3 years, or expected to be completed within 2021, by JINR students within the project, giving the student name, thesis title and graduation year –

1. I. Nemchenok - doctoral dissertation, 2019.

"Development and research of plastic and liquid scintillators for detectors of experiments in the field of neutrino physics".

2. A.V.Rahimov PhD thesis, 2021:

Radiochemical aspects of obtaining highly dispersed selenium-82 with a low content of radioactive impurities and analysis of materials for the low background studies.

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4. **Talks:**

-List the invited plenary talks given by members of the JINR group at international conferences, workshops… since the last approval of the project: give name and date of the conference, title of talk and speaker name.

-Give a similar list for parallel talks.

Plenary talks.

Yu.A. Shitov "The Final Results of the NEMO-3 Experiment and Status of the SuperNEMO Project", NUCLEUS-2019, Dubna, 1-5 July 2019.

V.I. Tretyak "Investigation of Mo-100 two-neutrino double beta decay in NEMO-3", MEDEX-2019, Prague, 27-31 May 2019.

PART B: Plans and requests

5. **Plans**

-Describe the plans of the JINR group within the project, in physics analysis, data taking, software development. detector R&D, detector operation and maintenance, upgrade activities… for the period of time of the requested extension.

Schedule. Installation of the Demonstrator in LSM is planned to be finished at **the end of 2022.**

2022 - completion of assembly and launch of the Demonstrator without neutron and iron shieldings. The calibration of the Demonstrator, the launch of data accumulation in a configuration without neutron shielding.

The first half of 2022 - the creation of neutron and iron shieldings of the Demonstrator.

The end of 2022 – start and calibration of data accumulation in the full configuration of the Demonstrator.

2022-2024 - data accumulation, data analysis. Determination of background. Fight with background if required and possible. Publication of results for the Demonstrator.

2022-2024 - R&D on: the centrifuge method of ^{96}Zr enrichment and radiochemistry purification, improvement of the purification technique of ^{82}Se (~100 kg) and mass production of plastic scintillators.

Physics goals and planned publications.

(1) Study of backgrounds. We plan to publish two or three articles. One for internal and external backgrounds (perhaps the very first publication with Demonstrator data). One is specifically about Radon. This will be very important for other experiments too, including searches for dark matter. And, perhaps, one article will cover the extrapolation of backgrounds on the sensitivity of the full SuperNEMO setup.

(2) One article will describe the SuperNEMO Demonstrator in NIM or JINST.

(3) There should be at least 3 articles on ^{82}Se. We already observe in NEMO-3 an indication that ββ-decay of ^{82}Se goes through ground state of intermediate nucleus (so called Single State Dominance (SSD) hypothesis for ββ-decay mechanism) in contradiction with theoretical expectations. With a higher statistics and lower background this effect should be very well visible in the Demonstrator. This may be one of the most important physical results of the Demonstrator. And of course, we will publish an article on 2νββ – 0νββ-decay ^{82}Se and separately on ββ-decay to excited states of ^{82}Kr.

(4) The study of "exotic" models: bosonic neutrinos, violation of the Lorentz invariance, the variation of the Fermi constant, and so on. This is possible due to registration of full pattern of ββ-decay (single electron energies and angle between their impulses) event in our method.

(5) Measurement of the conversion constants of radioactive isotopes. We already see with NEMO-3 that there are uncertainties in the tables, for example, for Pa-234m. For low-background experiments, the existing uncertainties become a problem. We are practically the only ones who can measure this with our system of radioactive calibration sources.

6. Group size, composition and budget

-List the JINR personnel involved in the project, including name, status (e.g. PI, researcher, post-doc, student, engineer, technician…) and FTE. Mention the total number of people in the collaboration.

The total number of people in collaboration: 95.

N	Person	Status	Subjects	FTE
1	O.I Kochetov	JINR Project Leader	calorimeter, data analysis, databases	1.0
2	Yu.A.Shitov	Senior Researcher	software, data analysis, databases	0.1
3	V.B.Brudanin	Senior Researcher	calorimeter, data analysis	0.1
4	3. A.A. Smolnikov	Senior Researcher	calorimeter, data analysis, simulation	0.3
5	4. A.A. Klimenko	Senior Researcher	software, data analysis	0.3
6	5. V.I. Tretyak	Senior Researcher	software, data analysis, simulation	1.0
7	7. D.V. Karaivanov	Researcher	radiochemistry, ^{82}Se-purification, sources	0.4

8	8. A.V. Rahimov	PhD student	radiochemistry, ^{82}Se purification, sources	0.6
9	9. D.V. Filosofov	Senior Researcher	radiochemistry, ^{82}Se purification, sources	0.3
10	10. N.A. Mirzaev	Researcher	radiochemistry, ^{82}Se purification, sources	0.4
11	12. A.V. Salamatin	Senior Researcher	electronics, cables	0.4
12	13. V.V. Timkin	Researcher	calorimeter, VETO system and cables	1.0
13	14. I.B. Nemchenok	Senior Researcher	PS production, calorimeter and VETO system	0.2
14	15. I.I. Kamnev	Engineer	PS production, calorimeter and VETO system	0.3
15	16. O.I. Vagina	Engineer	PS production, calorimeter and VETO system	0.3
In total				**6.7**

-Present the JINR group budget for the period of time of the requested extension, specifying the main budget items (equipment, computing, salaries, common funds, travel…)

Estimated expenditures for the SuperNEMO project

#	Designation for outlays	Total cost	1 year	2 year	3 year
	Direct expenses for the project				

1.	Networking	6.0 KUS$	2.0	2.0	2.0
2.	DLNP workshop	600 norm-hour	300	150	150
3.	JINR workshop	0	0	0	0
4.	Materials	290.0 KUS$	250.0	20.0	20.0
5.	Equipment	20.0 KUS$	20.0	0.0	0.0
6.	Collaboration fee	60.0 KUS$	20.0	20.0	20.0
7.	Salaries	341.7 KUS$	113.9	113.9	113.9
8.	Travel expenses	60.0 KUS$	30.0	15.0	15.0

Total **777.7 KUS$** **435.9 KUS$** **170.9 KUS$** **170.9 KUS$**

Expected salary of SuperNEMO team is 113.9 kUS$ per year. Estimation based on 2020 data and includes spending on technical personnel not listed in the project. 1US$ = 64RUB assumed in the estimation.

-Indicate the use or needs of JINR computing resources for the group and for the project if any.

The main IT resource of the SuperNEMO is the Lyon computer center of CNRS, funded from the general collaboration funds. JINR team uses the local resources available here (computers and equipment of department) for developing and debugging code and processing programs.